Mycorrhizal Fungi Diversity and Its Influencing Factors in Picea schrenkiana Forests of the Tianshan Mountains: A Postprint

Authors: Du Haiyan

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Abstract

Picea schrenkiana is the edificatory species of the Tianshan forests and holds an important position in the coniferous forests of northern China. In this study, mycorrhizal samples and surface soil samples were collected along an altitudinal gradient on the northern slope of the Tianshan Mountains, and molecular biology techniques were used to identify mycorrhizal fungi; simultaneously, soil organic carbon, total nitrogen (N), available phosphorus (P), and total potassium (K) contents were measured, and methods such as phylogenetic tree construction and canonical correspondence analysis (CCA) were employed to explore the diversity of mycorrhizal fungi in Picea schrenkiana forests and their influencing factors. The results showed: There were 21 species of mycorrhizal fungi in Picea schrenkiana forests, belonging to 2 phyla, 6 classes, 10 orders, 12 families, and 14 genera. Basidiomycota fungi were distributed in Picea schrenkiana forests at all altitudes, while Ascomycota fungi were mainly distributed in low-altitude Picea schrenkiana forests. With increasing altitude, mycorrhizal colonization rate and Shannon-Wiener index first increased and then decreased, ranging between 13%~36% and 1.14~2.03, respectively; the Simpson index, ranging between 0.49~0.63, showed a gradually decreasing trend; the evenness index, ranging between 0.47~0.63, first decreased and then increased with altitude. The distribution, colonization rate, and diversity indices of mycorrhizal fungi in Picea schrenkiana forests were mainly influenced by altitude and soil organic carbon content, while soil total nitrogen content only significantly affected the Shannon-Wiener index and evenness index. This study can provide a basis for the understanding and utilization of mycorrhizal fungal resources in Picea schrenkiana forests.

Full Text

Diversity of Mycorrhizal Fungi of *Picea schrenkiana* Forest and Its Affecting Factors in the Tianshan Mountains

DU Hai-yan[1], CHANG Shun-li[1], SONG Cheng-cheng[1], ZHANG Yu-tao[2]

[1]Key Laboratory of Oasis Ecology under the Ministry of Education, College of Resources and Environmental Science, Xinjiang University, Urumqi 830046, Xinjiang, China
[2]Institute of Forest Ecology, Xinjiang Academy of Forestry, Urumqi 830063, Xinjiang, China

Abstract

Picea schrenkiana is an edificator on the northern slope of the Tianshan Mountains and plays an important role in the coniferous forests in north China. In this study, mycorrhizal and topsoil samples were collected from the northern slope along an altitude gradient in the Tianshan Mountains. Mycorrhizal fungi were identified using molecular biology techniques, and soil organic carbon, total nitrogen, available phosphorus, and total potassium contents were measured. Phylogenetic analysis and canonical correspondence analysis (CCA) were used to investigate mycorrhizal fungal diversity and its influencing factors. The results showed that: (1) There were 21 mycorrhizal fungal species symbiotic with *P. schrenkiana* forest, belonging to 2 phyla, 6 classes, 10 orders, 12 families, and 14 genera; (2) Basidiomycota fungi were distributed across various elevation and altitude zones, while Ascomycota fungi were mainly distributed in low-altitude zones. With increasing altitude, the mycorrhizal infection rate (13%–36%) and Shannon–Weiner index (1.14–2.03) initially increased then decreased. Simpson' s index showed a gradual decreasing trend ranging from 0.49 to 0.63; the uniformity index varied from 0.47 to 0.63, first decreasing then increasing with altitude; (3) The distribution, infection rate, and diversity indices of mycorrhizal fungi were primarily affected by altitude and soil organic carbon content. Total nitrogen content significantly affected only the Shannon–Weiner index and uniformity index. This study provides a basis for understanding and utilizing mycorrhizal fungal resources of *P. schrenkiana*.

Keywords: mycorrhizal fungus; infection rate; species diversity; *Picea schrenkiana*; Tianshan Mountains

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2.3 Calculation of Diversity Indices

The Simpson index (D), Shannon–Wiener index (H), and Pielou uniformity index (J) were calculated using the following formulas:

$$D = 1 - \sum (P_i \ln P_i)$$

$$J = H / \ln S$$

where P_i represents the relative abundance of species i, and S is the total number of species.

2.4 Soil Nutrient Measurement

Soil organic carbon was measured using the potassium dichromate oxidation method. Total nitrogen was determined by the Kjeldahl method. Available phosphorus was extracted with sodium bicarbonate and measured by molybdenum-antimony colorimetry. Total potassium was measured by flame photometry after sodium hydroxide fusion.

**** The contents of C, N, P, and K at different sampling sites

Altitude (m)	Organic C (g · kg ¹)	Total N (g · kg ¹)	Available P (mg · kg ¹)	Total K (g · kg ¹)
1800–2000	116.19			
2000–2200	114.20			
2200–2400	169.56			
2400–2600	161.22			
2600–2800	114.11			

2.5 Molecular Identification

Total DNA was extracted from mycorrhizal samples using a DNA extraction kit. The ITS region was amplified with primers ITS1F and ITS4. PCR products were purified and sequenced. Sequences were compared against the NCBI database using BLAST, with similarity thresholds of 97% for species identification, 90% for genus identification, and <90% for family-level classification. Phylogenetic trees were constructed using MEGA 7.0 with the neighbor-joining method. Bootstrap analysis was performed with 1000 replicates. Coverage was calculated as: Coverage = (Number of observed OTUs / Total OTUs) × 100%.

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3 Results

3.1 Mycorrhizal Fungal Diversity A total of 21 mycorrhizal fungal species were identified from *P. schrenkiana* forest, belonging to 2 phyla (Ascomycota and Basidiomycota), 6 classes, 10 orders, 12 families, and 14 genera. [**Figure 1: see original paper**] shows the phylogenetic tree constructed using

the neighbor-joining method. [**Figure 2: see original paper**] illustrates the altitude distribution patterns of mycorrhizal fungal phyla.

Basidiomycota fungi were widely distributed across all altitude zones, while Ascomycota fungi were predominantly found in low-altitude zones (1800–2000 m). The 2000–2200 m zone exhibited the highest diversity, with both phyla present. **** presents the infection rates and diversity indices across altitude gradients.

**** Infection rate and diversity index of mycorrhizal fungi at different altitude gradients

Altitude (m)	Infection Rate (%)	Simpson Index (D)	Shannon–Wiener Index (H)	Uniformity Index (J)
1760–1980	32.58**	0.6313	1.8317	0.6103
1980–2200	36.15**	0.6234	2.0362	0.6345
2200–2400	17.68	0.5211	1.1032	0.4710
2400–2600	12.53	0.5016	1.1433	0.5211
2600–2800	13.01	0.4895	1.4316	0.6012

Note: ** indicates extremely significant difference ($P < 0.01$), * indicates significant difference ($P < 0.05$).

With increasing altitude, the mycorrhizal infection rate and Shannon–Weiner index initially increased then decreased, peaking at 1980–2200 m. Simpson' s index showed a gradual decreasing trend, while the uniformity index first decreased then increased.

[**Figure 3: see original paper**] shows the correlation between soil nutrient content (C, N, P, K) and mycorrhizal fungal phyla. Altitude and soil organic carbon content were the primary factors influencing mycorrhizal distribution and diversity. Total nitrogen content significantly affected only the Shannon–Weiner and uniformity indices ($P < 0.05$). The CCA analysis explained 88.8% of the variance in the first axis and 94.6% in the second axis, indicating strong relationships between environmental factors and fungal community composition.

4 Discussion

4.1 Factors Influencing Mycorrhizal Distribution Canonical correspondence analysis revealed that altitude and soil organic carbon content were the

dominant factors affecting mycorrhizal fungal distribution, infection rates, and diversity indices in *P. schrenkiana* forest. This finding aligns with previous studies demonstrating that elevation gradients strongly influence ectomycorrhizal community structure. The observed infection rates (8.36%–36.15%) fall within the typical range reported for coniferous forests (20%–90%).

The initial increase in diversity indices at mid-altitudes (2000–2200 m) followed by a decrease at higher elevations suggests optimal environmental conditions within this range. Basidiomycota dominated across all altitudes, while Ascomycota were restricted to lower elevations, possibly due to temperature and moisture constraints. Specific taxa such as *Tomentella* and *Sebacina* showed distinct altitude preferences, contributing to the observed diversity patterns.

Soil nutrients, particularly organic carbon, significantly influenced community composition. Total nitrogen affected only the Shannon–Weiner and uniformity indices, indicating differential sensitivity of diversity metrics to environmental variables. These results provide valuable insights for conservation and management of mycorrhizal resources in *P. schrenkiana* ecosystems, suggesting that altitude and soil carbon should be prioritized in future studies and forest management practices.

References

[1] Zhou Yueming, Chang Shunli, Zhang Yutao, et al. Study on air purification function of *Picea schrenkiana* forest in Tianshan Mountains[J]. Arid Zone Research, 2011, 28(4): 660–664.

[2] Wang Huijie, Chang Shunli, Zhang Yutao, et al. Density-dependent effects in *Picea schrenkiana* forests in Tianshan Mountains[J]. Biodiversity Science, 2016, 24(3): 252–261.

[3] Frank T, Beenken L, Döring M, et al. Arbuscular mycorrhizal fungi of the glomus-group lineage (Glomerales, Glomeromycota) detected in myco-heterotrophic plants from tropical Africa[J]. Mycological Progress, 2006, 5(1): 24–31.

[4] Smith SE, Read DJ. Mycorrhizal Symbiosis[M]. London, England: Academic Press, 1998: 41–52.

[5] Bahr M, Põlme S, Kõljalg U, et al. Regional and local patterns of ectomycorrhizal fungal diversity and community structure along an altitudinal gradient in the Hycanian forests of Northern Iran[J]. New Phytologist, 2012, 193(2): 465–473.

[6] Li Y, Wang S, Lu M, et al. Rhizosphere interactions between earthworms and arbuscular mycorrhizal fungi increase nutrient availability and plant growth in desertification soils[J]. Soil and Tillage Research, 2019, 186: 146–151.

[7] Reyes HA, Ferreira PFA, Silva LC, et al. Arbuscular mycorrhiza on *Pinus sylvestris* var. *mongolica* seedlings to the interaction between *Suillus luteus* and *Trichoderma virens*[J]. Current Microbiology, 2014, 69(3): 334-342.

[8] Gill WM, Lapeyrie F, Gomi T, et al. *Tricholoma matsutake*—an assessment of in situ and in vitro infection by observing cleared and stained whole roots[J]. Mycorrhiza, 1999, 9(4): 227-231.

[9] Kowalski T, Kehr RD. Two new species of *Phialocephala* occurring on *Picea* and *Alnus*[J]. Canadian Journal of Botany, 1995, 73(1): 26-32.

[10] George C, Wagner M, Kücke M, et al. Divergent consequences of hydrochar in the plant-soil system: Arbuscular mycorrhiza, nodulation, plant growth and soil aggregation effects[J]. Applied Soil Ecology, 2012, 59: 68-72.

[11] Crous P, Wingfield M, Burgess T, et al. Fungal Planet description sheets: 558-624[J]. Persoonia: Molecular Phylogeny and Evolution of Fungi, 2017, 38: 240.

[12] Koorsem K, Saks S, Söber V, et al. Effects of arbuscular mycorrhiza on community composition and seedling recruitment in temperate forest understory[J]. Journal of Vegetation Science, 2012, 80(2): 479-487.

[13] Zhang J, Wang P, Xue K, et al. Trait complementarity between fine roots of *Stipa purpurea* and their associated arbuscular mycorrhizal fungi along a precipitation gradient in Tibetan alpine steppe[J]. Journal of Mountain Science, 2019, 16(3): 542-547.

[14] Li Yuejiao, Zhu Liying, Yin Huajun, et al. Effects of 3-year continuous nighttime warming and nitrogen fertilization on ectomycorrhizae of *Picea asperata* and the ectomycorrhizal fungal diversity[J]. Acta Ecologica Sinica, 2015, 35(9): 2967-2977.

[15] Cai Xi-aobu, Peng Yuelin. Change of arbuscular mycorrhizal fungal community in response to elevational gradients on the Tibetan Plateau[J]. Chinese Journal of Applied Ecology, 2015, 26(9): 2803-2810.

[16] He Xueli, Wang Lingyun, Ma Jing, et al. AM fungal diversity in the rhizosphere of *Salvia miltiorrhiza* in Anguo City of Hebei Province[J]. Biodiversity Science, 2010, 18(2): 175-181.

[17] Wu Nan, Zhang Jing, Wang Yue, et al. Effects of snow cover and arbuscular mycorrhizal fungal network on the seedling growth of *Erodium oxyrhynchum*[J]. Arid Zone Research, 2018, 35(3): 624-632.

[18] Meng Fanrong, Shao Jingwen. Ectomycorrhizal fungi and their ecological distribution under coniferous forests in major forest areas of Northeast China[J]. Chinese Journal of Eco-Agriculture, 2007, 15(2): 201-204.

[19] Yang Xiuli. Mycorrhizal Diversity in the *Larix gmelinii* Forest Ecosystems of Da Xing' an Ling Mountains[D]. Hohhot: Inner Mongolia Agricultural University, 2010.

[20] Tuligur, Chen Jinchao, Wang Yao, et al. Macrofungal diversity in broad-leaved Korean pine forest in the Changbaishan National Nature Reserve[J]. Arid Zone Research, 2017, 34(1): 59-66.

[21] Zheng Di, Liu Zhihua, Guo Yao, et al. Seasonal variation of leaf traits of five eremophyte species in the Alxa desert[J]. Arid Zone Research, 2017, 34(4): 823-831.

[22] Ren Yuntao, Zhang Chenxi, Shang Zhanyan, et al. Seasonal variation of leaf traits of five eremophyte species in the Alxa desert[J]. Arid Zone Research, 2017, 34(4): 823-831.

[23] He Xiaoxiang, Tan Zhoujin, Xiao Qiming, et al. A review on the functions of ectomycorrhiza and the effects of environmental factors on them[J]. Chinese Journal of Eco-Agriculture, 2007, 15(2): 201-204.

[24] Meng Fanrong, Shao Jingwen. Ectomycorrhizal fungi and their ecological distribution under coniferous forests in major forest areas of Northeast China[J]. Chinese Journal of Eco-Agriculture, 2007, 15(2): 201-204.

[25] Li Y, Wang S, Lu M, et al. Rhizosphere interactions between earthworms and arbuscular mycorrhizal fungi increase nutrient availability and plant growth in desertification soils[J]. Soil and Tillage Research, 2019, 186: 146-151.

[26] Gill WM, Lapeyrie F, Gomi T, et al. *Tricholoma matsutake*—an assessment of in situ and in vitro infection by observing cleared and stained whole roots[J]. Mycorrhiza, 1999, 9(4): 227-231.

[27] Kowalski T, Kehr RD. Two new species of *Phialocephala* occurring on *Picea* and *Alnus*[J]. Canadian Journal of Botany, 1995, 73(1): 26-32.

[28] George C, Wagner M, Kücke M, et al. Divergent consequences of hydrochar in the plant-soil system: Arbuscular mycorrhiza, nodulation, plant growth and soil aggregation effects[J]. Applied Soil Ecology, 2012, 59: 68-72.

[29] Crous P, Wingfield M, Burgess T, et al. Fungal Planet description sheets: 558-624[J]. Persoonia: Molecular Phylogeny and Evolution of Fungi, 2017, 38: 240.

[30] Koorsem K, Saks S, Söber V, et al. Effects of arbuscular mycorrhiza on community composition and seedling recruitment in temperate forest understory[J]. Journal of Vegetation Science, 2012, 80(2): 479-487.

[31] Zhang J, Wang P, Xue K, et al. Trait complementarity between fine roots of *Stipa purpurea* and their associated arbuscular mycorrhizal fungi along a precipitation gradient in Tibetan alpine steppe[J]. Journal of Mountain Science, 2019, 16(3): 542-547.

[32] Li Yuejiao, Zhu Liying, Yin Huajun, et al. Effects of 3-year continuous nighttime warming and nitrogen fertilization on ectomycorrhizae of *Picea asperata* and the ectomycorrhizal fungal diversity[J]. Acta Ecologica Sinica, 2015, 35(9): 2967-2977.

[33] Cai Xi-aobu, Peng Yuelin. Change of arbuscular mycorrhizal fungal community in response to elevational gradients on the Tibetan Plateau[J]. Chinese Journal of Applied Ecology, 2015, 26(9): 2803-2810.

[34] He Xueli, Wang Lingyun, Ma Jing, et al. AM fungal diversity in the rhizosphere of *Salvia miltiorrhiza* in Anguo City of Hebei Province[J]. Biodiversity Science, 2010, 18(2): 175-181.

[35] Wu Nan, Zhang Jing, Wang Yue, et al. Effects of snow cover and arbuscular mycorrhizal fungal network on the seedling growth of *Erodium oxyrhynchum*[J]. Arid Zone Research, 2018, 35(3): 624-632.

[36] Meng Fanrong, Shao Jingwen. Ectomycorrhizal fungi and their ecological distribution under coniferous forests in major forest areas of Northeast China[J]. Chinese Journal of Eco-Agriculture, 2007, 15(2): 201-204.

[37] Zheng Di, Liu Zhihua, Guo Yao, et al. Seasonal variation of leaf traits of five eremophyte species in the Alxa desert[J]. Arid Zone Research, 2017, 34(4): 823-831.

[38] He Xiaoxiang, Tan Zhoujin, Xiao Qiming, et al. A review on the functions of ectomycorrhiza and the effects of environmental factors on them[J]. Chinese Journal of Eco-Agriculture, 2007, 15(2): 201-204.

[39] Yang Xiuli. Mycorrhizal Diversity in the *Larix gmelinii* Forest Ecosystems of Da Xing' an Ling Mountains[D]. Hohhot: Inner Mongolia Agricultural University, 2010.

[40] Tuligur, Chen Jinchao, Wang Yao, et al. Macrofungal diversity in broad-leaved Korean pine forest in the Changbaishan National Nature Reserve[J]. Arid Zone Research, 2017, 34(1): 59-66.

[41] Ren Yuntao, Zhang Chenxi, Shang Zhanyan, et al. Seasonal variation of leaf traits of five eremophyte species in the Alxa desert[J]. Arid Zone Research, 2017, 34(4): 823-831.

Note: Figure translations are in progress. See original paper for figures.